LONG-TERM ECOLOGICAL RESEARCH

Ecology has taken its place among science's vital, strategic disciplines, thanks to ever-greater awareness of how the web of life and Earth's other dynamic processes constitute a closed and coherent system. As part of this evolution, NSF's Long-Term Ecological Research Program (LTER), begun in 1980, has grown into a network of 24 research sites, established to acquire long-term data sets from Alaska to Puerto Rico to Antarctica. Such a geographical spread is necessary to collect information on a variety of ecosystem types; such as, grassland, desert, forest, tundra, lake, stream, river, agricultural and coastal systems.

To enhance understanding of ecological phenomena, the program focuses on the role of cyclical/episodic events (ranging from years to decades to centuries) in the structure and function of these distinctive ecosystems. The Antarctic Biology and Medicine Program supports two of these LTER project sites to facilitate research on unique aspects of antarctic ecology; one near Palmer Station in the Antarctic Peninsula, and the other in the McMurdo Dry Valleys.

The Palmer Station/Antarctic Peninsula LTER program is ideally sited to probe a fundamental issue: As the pack ice varies (seasonally and year-to-year), what happens to the antarctic marine community; that is, how do ecological processes influence organisms at different trophic levels? The Palmer Station LTER research program was initiated during the 1991-1992 season with the installation of an automatic meteorological station, annual research cruises in the austral summer, and a focused research program at the station facility. During the austral fall and spring seasons, process-study research cruises develop data that can be compared to that collected from other coastal systems in the Antarctic Peninsula.

The McMurdo Dry Valleys LTER project is more wide-ranging - due to its unique site - and stages interdisciplinary study of aquatic and terrestrial ecosystems in a cold desert region of Antarctica. The area is one of the most fascinating and contrarian spots on Earth. In fact, it is as unearthly as any; NASA scientists wondering what conditions on Mars might be like came here - an island of rock in a sea of ice, the largest ice-free area in Antarctica - where winds howl, what little water there is dessicates or evaporates, and where the only creatures that can survive are microorganisms, mosses, lichens, and relatively few groups of invertebrates; higher forms of life are virtually non-existent.

Thus, LTER projects based here take advantage of perhaps the coldest and driest ecosystem on Earth, where life approaches its environmental limits; as such this may be seen as an "end-member" in the spectrum of environments included in the LTER network. Why is it necessary to conduct long-term ecological research in such a place? All ecosystems are dependent upon liquid water and are shaped to varying degrees by climate and material transport; but nowhere is this more apparent than in the McMurdo Dry Valleys. In very few of Earth's environments do minor changes in solar radiation and temperature so dramatically affect the capabilities of organisms to grow and reproduce as happens in the dry valleys. Thus, this site may well be an important, natural, regional-scale laboratory for studying the biological effects of climate changes attributable to human activity. While the antarctic ice sheets respond to climate change on the order of thousands of years, the glaciers, streams, and ice-covered lakes in the McMurdo Dry Valleys often experience nearly immediate (and sometimes profound) change. As such, this area would be one of the first where the effects of climate change in Antarctica should be observed.

The overall objectives of the McMurdo Dry Valleys LTER are to understand the influence of physical and biological constraints on the structure and function of dry valley ecosystems and to understand the modifying effects of material transport on these e cosystems. Though driven by the same basic processes found in all ecosystems (for example, microbial use and re-mineralization of nutrients) these dry valley ecosystems lack many of the confounding variables - such as diverse and fecund biota and many levels of plants and higher animals - indigenous to other ecosystem research.

Long-term ecological research on the antarctic marine ecosystem, an ice dominated environment: The Palmer LTER program.
Raymond Smith, University of California at Santa Barbara.

The Palmer Long-Term Ecological Research (LTER) project is focused on one major ecological issue: To what extent does the advance and retreat of sea ice each year physically determine spatial and temporal changes in the structure and function of the antarctic marine ecosystem? Evidence shows this dynamic variability of sea ice to have an important (perhaps determinant) impact on all levels of the food web, from total annual primary production to breeding success in top predators. For example, variability in sea ice may affect prey and predators directly by controlling access to open water or preferred habitats; or indirectly, as changes in the sea-ice cover affect other species that serve as food. Four hypotheses driving our research are that sea-ice is a major factor that regulates:

• the timing and magnitude of seasonal primary production;

• the dynamics of the microbial loop and particle sedimentation;

• krill abundance, distribution, and recruitment; and

• survivorship and reproductive success of top predators.

These factors probably differ for key species, as the magnitude and timing of sea-ice changes can have specific local impacts. What remains unclear are the ramifications for the whole antarctic ecosystem. As one of the basic examples: Greater sea-ice areal coverage promotes more available krill (a primary food), which enhances the survivorship and reproductive success of Adélie penguins. Overall objectives of the Palmer LTER project are to

• document not only the interannual variability of annual sea ice and the corresponding physics, chemistry, optics, and primary

production within the study area, but also the life-history parameters of secondary producers and top predators;

• quantify the processes that cause variation in physical forcing, and the subsequent biological response, among the representative trophic levels;

• construct models that will link ecosystem processes to environmental variables and which will also simulate spatial/temporal ecosystem relationships; and

• employ such models to predict and validate ice/ecosystem dynamics.

A key challenge for the Palmer LTER project is to characterize and understand the many cross-linkages that have developed in the antarctic ecosystem. Environmental phenomena vary, over time and across areas, having both physical and biological consequences; these changes in turn can develop other loops and linkages that influence each other.

The participants for the 2001-2002 field season will be:

• William Fraser, Montana State University (BP-013-O);

• Maria Vernet, Scripps Institution of Oceanography (BP-016-O);

• Douglas Martinson, Columbia University (BP-021-O);

• Langdon Quetin and Robin Ross, University of California at Santa Barbara (BP-028-O);

• Raymond Smith, University of California at Santa Barbara (BP-032-O); and

• David Karl, University of Hawaii (BP-046-O).

The role of natural legacy on ecosystem structure and function in a polar desert: The McMurdo Dry Valley LTER program.
W. Berry Lyons, Ohio State University.

The largest ice-free area in Antarctica can be found in the McMurdo Dry Valleys, located on the western shore of McMurdo Sound. Among the most extreme deserts in the world, the dry valleys are the coldest and driest of all LTER sites. Consequently, the biological systems are limited to microbial populations, microinvertebrates, mosses, and lichens. Yet complex trophic interactions and biogeochemical nutrient cycles develop in the lakes, streams, and soils of the Dry Valleys. In the austral summer, solar energy produces glacial meltwater, providing vital water and nutrients that have a primary influence on the ecosystems. Such material transport and climatic influences shape all ecosystems, but nowhere is this more apparent than in the McMurdo Dry Valleys

In 1993, this region was selected as a study site for the National Science Foundation's Long-Term Ecological Research (LTER) program. During the first 6 years of this project, investigators studied the perennially ice-covered lakes, ephemeral streams, and extensive areas of soil to assess the role of physical constraints on the structure and function of the ecosystem. Clearly, the production of liquid water in both terrestrial and aquatic portions of this environment is a primary driver in ecosystem dynamics. Thus, the role of present-day climate variation is extremely important. However, one of the most significant discoveries was that past climatic legacies strongly overprint the present ecological conditions in the McMurdo Dry Valleys.

The McMurdo LTER project focuses on the aquatic and terrestrial ecosystems in the dry valley landscape as a context to study biological processes and to explore material transport and migration. During the second phase of this LTER project, we are extending our research by continuing to investigate the McMurdo Dry Valleys as an "end-member" system, hoping to better ascertain the role of the past climatic legacies on ecosystem structure and function. We will test a series of eight hypotheses in three major focus areas - hydrology, biological activity/diversity, and biogeochemical processes - by continuing monitoring projects and long-term experiments.

Understanding the structure and function of the McMurdo Dry Valleys ecosystem requires deciphering the hydrological response to climate - both now and in the past. Current patterns of biological activity and diversity reflect both past and present distributions of water, nutrients, organic carbon, and biota. Biogeochemical processes responsible for the transport, immobilization, and mineralization of nutrients and other chemicals provide the linkages between the region's biota and the physical environment. The timing, duration, and location of biogeochemical processes - in the past and present - are controlled by water availability. We continue to focus on the integration of the biological processes within and among the lakes, streams and terrestrial ecosystems that comprise the McMurdo Dry Valley landscape. Our interdisciplinary research team will continue to use modeling and other integrative studies to synthesize data and to examine the McMurdo Dry Valleys ecosystem.

During the 2001-2002 field season, the following studies will be conducted in the McMurdo Dry Valleys as part of the LTER project:

• Paleoclimatology, paleoecology and meteorological data collection. (BM-042-D)
Peter T. Doran, University of Illinois at Chicago.

• Glacier mass balance, melt, and energy balance; climate monitoring in Taylor, Wright, Victoria, and Beacon valleys. (BM-042-F)
Andrew Fountain, Portland State University.

• Chemistry of streams, lakes, and glaciers. (BM-042-L)
W. Berry Lyons, Ohio State University.

• Flow, sediment transport, and productivity of streams; water quality of Lake Fryxell; water loss from the streams to the atmosphere by sampling water-content changes. (BM-042-M)
Diane McKnight, University of Colorado

• Lake pelagic and benthic productivity; microbial food webs. (BM-042-P)

John Priscu, Montana State University at Bozeman.

• The influence of environmental conditions on carbon and nitorgen cycling and on soil biota; the effects of environmental change and food supply availability on soil biota; and the effects of climate change on biota. (BM-042-W)
Diana Wall, Colorado State University;
(BM-042-V)*Ross A.Virginia, Dartmouth College.*

Transport and fate of persistent organic pollutants (POPs) in antarctic coastal seas.
Hugh Ducklow, College of William and Mary.

Being distant and largely isolated from the industrialized world, the antarctic region is typically considered pristine. In the last two decades, however, concern about long-range atmospheric transport of persistent organic pollutants (POPs) has escalated throughout the global environment. POPs are highly stable organic compounds that persist in the environment, accumulate in the fatty tissues of most living organisms and are generally toxic to humans and wildlife. They come from pesticides, industrial and combusion processes.

But Antarctica is not just another place that could suffer the random, transboundary drifting of these noxious substances. Its polar location and unparalleled climatic characteristics raise unique issues of atmospheric transport, cold condensation, and deposition on sea ice. Because the climate changes so dramatically, sea ice comes and goes - covering as little as 4 million square kilometers (sq km) in February to as much as 20 million sq km in September. Vast webs of microbial life undergo seasonal production and decomposition. Antarctic food webs are thus vulnerable to those POPs that do migrate this far.

Cooperating with the Palmer Long-Term Ecological Research program (LTER) and sailing on their R/V Nathaniel B. Palmer winter cruise, we hope to document the accumulation of selected model POPs in sea-ice and the water column along the west Antarctic Peninsula. We also hope to add to the burgeoning global dataset on the biological/chemical processes that influence the rate of POP decline, turnover and residence time. (BP-045-O)

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